# Mach 2

## Concorde magazine

### The high life
*Concorde's most eminent passengers*

### An unusual display
*Concorde visits Jakarta*

### Beating heart
*The source of Concorde's power*

### Concorde watch
*News from Orly and Seattle*

Issue 9
April 2017

# Introduction

*In this issue we are delighted to present our first contributions from Captain Derek Woodley (BA Concorde Training Standardisation Captain 1994–2003). Captain Woodley recalls an exciting visit with G-BOAD to the Indonesian Airshow in Jakarta in 1998. More recently, he visited G-BOAG in her new home in Seattle, and he shares his views following the personal tour that the Museum of Flight gave him.*

*Our regular contributor Captain Christopher Orlebar recalls his encounters with some of the world-renowned people who travelled on Concorde flights – including a personal chat with a former Prime Minister.*

*Nigel Ferris gives an insight into the "beating heart" of Concorde – the system of air intakes, engines, and nozzles that enabled the aircraft, uniquely among passenger transports, to maintain supersonic speed for hours, yet with maximally efficient use of energy.*

*In addition, we have our regular Tech Log, with flight engineer Ian Kirby, and Concorde Watch news from France and Seattle.*

## In this issue



Editor: Katie John
Contributing editor: Nigel Ferris
Cover photo: johnrp / Pixabay

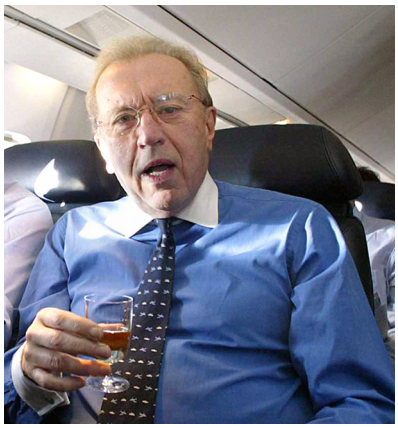
# Transport for the elite

*Christopher Orlebar, former Concorde pilot with British Airways*

*Christopher Orlebar recalls some of the famous passengers that he met while flying Concorde – including eminent politicians, film stars and musicians, other media figures, and war veteran and humanitarian Leonard Cheshire.*

Concorde attracted an elite group of people such as broadcaster Sir David Frost. He stated that Concorde was the only aircraft that allowed him to be in two places at the same time.

Sir David was referring to the westbound flight, which delivered him to New York an hour earlier than he had left London. Eastbound, however, in terms of local time it took about nine hours. However, when flying east with the spin of the earth, things and people weigh about 3% less. The reduction of gravity is due to the angular velocity round, and distance from, the earth. It is not a question of losing mass, just weight, thereby justifying the superb supersonic cuisine and the excellent wine cellar.



**Frequent flier**
Sir David Frost, seen here on a flight from Heathrow to JFK.
*Photo: Press Association*

## Flying into yesterday

"Hello lads," this friendly greeting came from Sir Paul McCartney. In the days when the passengers were allowed to visit the cockpit during flight, Sir Paul had been ushered in. He said how privileged he was to come and see us. We said it was the other way round. Flying westward at 1,350 mph the sun was rising, but from the west. I suggested to him that the title of his next album should be "Flying into yesterday." He has not as far as I know taken up the idea; but it still may happen.

## War heroes

Over the years the Concorde crews hosted many celebrities. Another was Leonard Cheshire VC, the highly decorated RAF pilot who had survived many more raids over Germany than statistics allowed. At 27 years old he became the youngest man ever to have been promoted to Group Captain. On 9 August 1945 he observed through welder's goggles from 39,000ft the detonation of the second atomic bomb to be dropped on Japan. In the mid eighties as guest speaker at the annual dinner held by the Concorde Dining Society at the RAF Club in Piccadilly, he defended the principle of nuclear deterrence.

"I've not seen anything like this since the war," said actor Sir John Mills, another war veteran, at the end of the landing run. I must admit that neither had we. The temperature was below zero and the snow was swirling in snakes down the runway at Heathrow. Quite what he had seen in the war was not clarified.

## Fascinated by Concorde

On a lighter occasion Elizabeth Taylor was installed on the jump seat and was lent a headset to listen to the intercom and R/T. She was, for some reason, intrigued by the movement of the nose and visor. So whenever it was about to be moved someone told her "Miss Taylor to watch the nose," she reacted with youthful pleasure.

**Serving officer**
Group Captain Leonard Cheshire VC, OM, DSO & Two Bars, DFC.
*Source: RAF / HMSO*

Mohammed Ali, who was into writing poetry, wrote a poem and alluded to it being the fastest he had ever written. Ted Heath, former Prime Minister en-route to the States to launch his book, appeared serious and remained uncommunicative. I wonder what he would have said about Brexit.

Yuri Geller bent spoons for us on the flight deck and then offered to spin the compass, provided we shut the cockpit door. I looked at the compasses run by the inertial navigation system, now referenced to true north for our Atlantic crossing, and wondered how the auto pilot would react. He put his head next to the standby compass on the pillar between the windscreens. To our astonishment it whizzed round. I looked at him thinking that he must have had an electro magnet surgically inserted in his forehead;

**Harold Macmillan**
Prime Minister when the Anglo-French agreement was signed to build what became Concorde.
*Photo: National Archives, UK*

reading my mind, he denied having any artificial assistance; but then he would say that, wouldn't he?

## Meeting Macmillan

My most telling encounter was with Sir Harold Macmillan. In 1979 and 1980 BA and Singapore Airlines had joined forces to fly a supersonic service three times a week from London to Singapore via Bahrain, and then perhaps on to Australia. Macmillan was flying out to Singapore en-route I believe to China.

After landing at Bahrain he was allowed to stay on board with his valet. The other 70 passengers had disembarked whilst the aircraft was cleaned. I realized that this would be the only chance I would ever have of meeting him. So without telling anybody who might have said "no", I went back to introduce myself.

I said clearly that I was the first officer "Christopher Orlebar"; he replied with equal clarity, as if I did not know, that he was "Harold Macmillan". Since he had been the British Prime Minister in 1962 when the treaty was signed with France to build a supersonic airliner, I thought it fair to ask why there had not been a production line for Concorde "as long as your arm". He immediately replied "American jealousy, my dear boy, American jealousy."

## Supersonic superstars

Concorde's passengers included famous figures from across the world and all areas of public life; a selection of these eminent people is listed here.

**Queen Elizabeth II**
HM Queen Elizabeth II and Prince Philip disembark from a British Airways Concorde at Bergstrom Air Force Base, Texas, on their state visit to the USA in 1991. The Royal Family were frequent travellers on Concorde; the late Queen Mother even enjoyed a visit to the flight deck on her 85th birthday.
*Photo source: SRA Jerry Wilson / US Department of Defense*

**Royal personages**
Queen Elizabeth II
Prince Philip
Queen Mother
Prince Charles
Princess Diana

**Religious leaders**
Pope John Paul II
Robert Runcie (former Archbishop of Canterbury)
HH The Dalai Lama

**British political leaders**
James Callaghan
Tony Benn
Margaret Thatcher
John Major
Tony Blair
Gordon Brown

**French Prime Ministers**
Valéry Giscard d'Estaing
François Mitterrand
Jacques Chirac

**Film stars**
Elizabeth Taylor
Joan Collins
Sean Connery
Robert Redford
Richard Gere

**Music stars**
Paul McCartney
Sting
Phil Collins
Bruce Springsteen
Bee Gees
Madonna
Diana Ross
Elton John

**Also:**
Leonard Cheshire (humanitarian)
David Frost (broadcaster)
Jodie Kidd (model)
Luciano Pavarotti (opera singer)
Ryder Cup golf team

# Journey to Jakarta

*Our latest Mach 2 contributor, BA Concorde captain* Derek Woodley *(Training Standardisation Captain, BA Concorde Fleet 1994–2003), recalls putting Concorde G-BOAD through her paces during a flight to the 1996 air show in Jakarta, Indonesia.*

In the summer of 1996 British Aerospace were keen to become involved in aircraft production in Asia. Maybe they saw an opportunity to manufacture and promote British aviation designs in that part of the world. I remember they were very hopeful of securing a local manufacturing arrangement to produce the Hawk Trainer aircraft in Indonesia. In order to promote this, British Aerospace were persuaded by the organisers of the Indonesian Airshow in Jakarta to arrange for Concorde and the Red Arrows to appear at their show.

Although by that time British Airways had banned Concorde from flying at air shows, British Aerospace chartered a Concorde to fly into Jakarta to effectively open the Airshow and to remain as a static exhibit during the show, and then to close the show on departure. In addition, the Red Arrows did their display a few times during the week.

## Travelling east

Flying Concorde out to Indonesia was an interesting experience. It certainly made a welcome change from the usual LHR – JFK – LHR flights that were our normal remit!

It was decided that we needed two refuelling stops on the way as we were carrying a full complement of 100 British Aerospace guests and employees as passengers. Jeddah in Saudi Arabia was the first stop for a crew change and for fuel. I joined the aircraft there and commanded AD for the rest of the trip.

When we departed Jeddah it was already dark, and as our flight route took over what we thought were sparsely populated areas, we chanced our luck after departure by requesting permission from Air Traffic Control to climb to 60,000 ft. Remember Concorde is supersonic when above 30,000 ft, so we were effectively asking to go supersonic over land! Whether ATC realised this I am not sure, but we got our clearance, climbed and accelerated, and enjoyed a very efficient flight to our next stop at Colombo in Sri Lanka.

We landed in Colombo at dawn and refuelled quickly. There was just time for a couple of Breakfast TV interviews on the tarmac at the bottom of the aircraft steps before we flew on to Jakarta.

## Perfect conditions

AD was in her element in these more equatorial latitudes. Temperatures at our cruise altitude were low; our engines therefore ran very efficiently and we were soon cruising at 60,000 ft, maintaining Mach 2 throttled back, and well above the turbulent thunder clouds. AD had been in this part of the world before as she was the Concorde painted with Singapore Airline colours on one side during the short-lived scheduled supersonic services to Singapore in the early 1980s.


**Double identity**
G-BOAD at Heathrow in the 1970s; while flying for Singapore Airlines, the aircraft was painted with Singapore's livery on the port side and BA livery on the starboard side.
*Photo: © Steve Fitzgerald (Wikimedia Commons; supplied under the GNU Free Documentation License, Version 1.2)*

Our route was carefully planned to keep us over water and therefore supersonic for the whole flight, but some careful navigation between islands was needed as we approached Indonesia.

We landed in very hazy conditions at Jakarta to find there was massive press interest


**Star turn**
G-BOAD performs a low-level flypast at Farnborough, September 1986 – showing the star quality that made Concorde such a huge attraction at air shows.
*Photo: © Tim Rees (Wikimedia Commons; GNU Free Documentation License, Version 1.2)*

in our arrival. Lots of TV coverage, interviews, etc. It was as if Concorde was a brand new design, and bearing in mind that by then we had been operating across the Atlantic supersonically for 18 years, I was more than a little surprised!

## Impressive displays

Concorde AD remained in the static display for the duration of the show. Visits on board were restricted for security reasons to only those within the aviation industry; we were not open to the public. Pilots of many nationalities were very keen to have a look at our flight deck, especially some Russian MIG 29 and Sukhoi 30 pilots, who asked some very searching questions! Hmmm!

We flew once during the week. British Aerospace had discovered it was the birthday of the Indonesian Minister for Aviation, the organiser of the show, and asked us to take him for a ride. We flew south supersonically from Jakarta towards Australia, turned around Christmas Island, then back to Jakarta. During the flight a huge birthday cake was produced, that was cut with a jewel-encrusted sword!! So much for security – British Aerospace must have been very keen to impress the Indonesians and secure a contract.

Concorde made many friends and had many admirers during that week; it was a great privilege to have been part of the event.

## Returning home

We departed in as spectacular a fashion as we could, bearing in mind we had 100 passengers on board – but then every Concorde take-off is spectacular anyway. We turned away from the airfield, headed out over the Indian Ocean, reheats on, and hopefully created a good photo opportunity!

The return flights back to the UK went perfectly – the only difference being that the Saudi Arabian authorities insisted that we were at subsonic speed 40 miles before their coastline, even though it was dark. Somebody had obviously noticed our tactic on the outbound leg.

G-BOAD performed flawlessly during this whole trip. Although we did have a limited supply of spares with us, none were needed. My personal view is that AD was the best Concorde in the BA fleet. Maybe that is because it was the first Concorde I ever flew during training? It certainly consumed less fuel than most, and of course this aircraft holds the record for the fastest Atlantic crossing, set in 1996.

# Intakes, engines, exhausts

*Nigel Ferris, Contributing Editor*

Nigel Ferris *gives his personal understanding of the crowning glory of Concorde – the system of air intakes, engines, and exhausts that gave the aircraft her unequalled speed and power.*

What made Concorde special? Not just her beauty, grace and power – and the ability to turn heads whenever she flew. There are many things about Concorde that make her unique in the world of commercial aviation.

Some of the notables (and firsts) include (in no particular order):

- the ability to fly 100 passengers at Mach =2.0 in shirt-sleeved luxury
- the first airliner to be controlled by 'fly by wire'
- extremely powerful carbon fibre disc brakes
- shortening undercarriage on retraction (since utilised on the bigger Airbus aircraft)
- expansion of the airframe at supercruise (the ability of an aircraft to sustain high Mach numbers without the use of thrust augmentation)
- fuel transfer along the length of the aircraft to maintain the C of G position as the centre of lift moved rearwards at high speed
- the famous droop nose; superior tyre technology to allow take-off speeds of up to 220 knots (250 mph)
- the unique droop, twist and camber of the wing design to cater for low- and high-speed flight.

You will be aware of most, if not all, of these factors, but I thought I would concentrate on the 'beating heart' of the aircraft – the intakes, engines, and exhausts.

## An integrated system

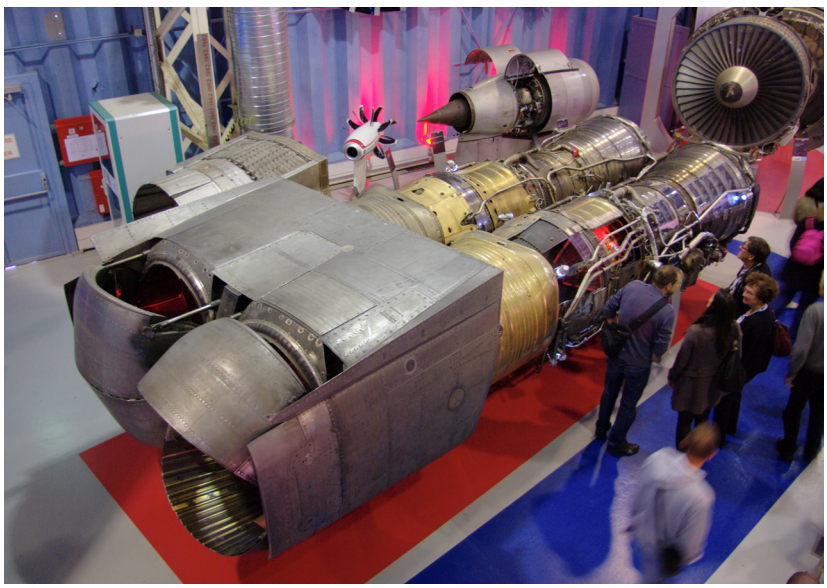
On a walk around under Concorde, and inspecting the engine nacelle assemblies, visitors could be excused for thinking it was just intakes bolted to engines, and engines bolted to exhausts, and then attached to the wings. This is where it gets all very clever.

The Rolls Royce Olympus 593/610 engines can be described as axial flow, twin spool, afterburning turbojets, with computer-controlled intakes (converted from analogue to digital during prototype and pre-production aircraft flight testing), analogue computer-controlled fuel control, primary and secondary nozzles, reheat, and reverse thrust.

## Controlling airflow

Modern aircraft have high by-pass ratio turbo fan engines, with a very large fan at the front and a relatively small engine core. They can produce up to and over 100,000 lb of thrust, with some 70% of that thrust coming from the fan. Any jet engine will start to suffer if it receives more air than it can handle, at more than Mach =0.5, approx 350 mph – the compressor blades will achieve that airspeed by compressing the incoming air and therefore lowering the speed. The intakes were a convergent/divergent system – the convergent passage slows and compresses a supersonic airflow; the divergent passage slows and compresses a subsonic airflow.

Now it starts to get really clever in the case of Concorde, and the secret of her flying prowess. Travelling at Mach =2.0, 1350 mph, at 58–60,000 ft, how does the engine get its preferred 350 mph air intake speed – and how do we shed 1000 mph of incoming air speed? The combination of controlled intakes, controlled engines, and controlled exhausts (also a con/di system) does the job. Superbly. And if the word wizardry could be used here, that is what it seems like.



**Engines and nozzles**
In this display, at the Musée Safran near Paris, a pair of Olympus 593 engines has been joined to a reverse thrust assembly to show the layout as it would be in an actual aircraft.
*Photo: Duch / Wikimedia Commons*

## Intakes and reheats

On take-off, with each engine and reheat producing 38,050 lb of thrust (20% of that from the reheats), the air demands of the engine were very high. (Over 7 tons of air per minute per engine – see the Tech Log reply from Ian Kirby.) In the intake section, underneath, were blow-in doors which would open and allow extra air into the engines, dependent on the air demands of the engine, and held open aerodynamically, not closing until approx Mach =0.95. They would also be open during landing, again when engine requirement air would be supplied.

At this number, Mach =0.95, the power levers would be advanced to maximum, the reheats selected (in pairs as all four at once would give quite a pronounced 'kick in the back' for the passengers), and the aircraft would start to accelerate. At Mach 1.3, the intake magic began to operate. Specially designed and shaped ramps (now the intellectual property of Airbus, and still largely secret) in the roof of the intakes would start to descend, until they reached a position where a shock wave was focussed at the lower lip of the intakes, slowing the air and compressing it at the same time. Incidentally, each of the 4 intakes were slightly different in design. So in about 12ft, the Olympus engines were getting their air at the optimum speed of 350 mph – a loss of 1000 mph of intake air speed. Then at Mach =1.7 the reheats would shut off, and the aircraft would continue to accelerate as the fuel burnt off and she became lighter, up to Mach 2, reached at 50,000 ft.


**Air intakes**
This view into the air intakes shows the ramps (turbochargers!) at the front of the intakes and the dump doors (seen at the base of the picture) in the fully down position.
*Photo: Dockurt2k / Wikimedia Commons*

## Power and efficiency

The story doesn't end there, though. The twin spool design comprised a low pressure compressor at the front of the engine (7 turbine stages; the N1 reading) and a high pressure compressor (7 turbine stages), further back (the N2 reading). The relationship and matching between these two rotating fan masses was critical, and this was partially achieved by the primary nozzles. Situated at the end of the engine, they were movable petals around the circumference of the jet pipe, and would move to control the rotation speed of the low pressure compressor (N1). In doing so, the petals could make a smaller area for the exhaust, making it travel faster. (Think of a hosepipe – put your finger over the end, restricting the cross-sectional area of the end of the pipe, and the speed and force of the outflowing water becomes greater as the pressure behind the water remains the same, and the water has to speed up to get out.) This, in effect, was one way the primary nozzles contributed to the total thrust produced to maintain high-speed flight. The rotation speed of the high pressure compressor (N2) was directly controlled by the amount of fuel supplied to the injector nozzles, as directed by the power lever settings, through the throttle amplifiers and the electronic control boxes. The N1 and N2 rotation speed of the turbines was referred to as percentage RPM.

This close relationship between the two spools ensured maximum efficiency of the engines; indeed the Olympus 593s were extremely efficient at Mach =2.0, with a low fuel burn. Imagine a turbocharger fitted to a car engine – the purpose being to increase the amount of air in a compressed state into the engine combustion chambers, allowing more fuel to be injected, providing more power (admittedly using engine power to drive the turbo). Concorde obtained this power boost for free, using the forward motion through the air to generate the boost. The overall pressure ratio across the engine was 80/1. So the intakes on Concorde can rightly be regarded as giant turbochargers.

The secondary nozzles (reverse thrust buckets) at the rear of the engine were in a slightly closed position during take-off – this was to allow air to surround the jet efflux, aiding noise reduction. They would be fully open during Mach =2.0, and of course fully closed on landing to effect (very powerful) reverse thrust.

At take-off and subsonic speeds, the majority of the thrust came from the engines, and the rest from the intakes and exhausts. At Mach =2.0 the engines provided 10,000 lb of the thrust, with the remainder from the exhausts, primary and secondary nozzles, and of course the intakes – our highly efficient turbochargers!

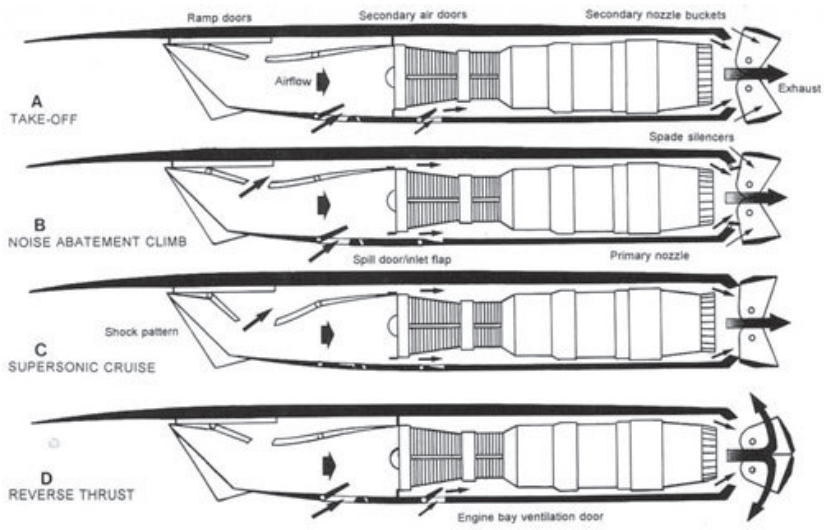
Conventional airliners have swept wings to give good lift at speed (550 mph typical), with leading-edge slats and trailing-edge flaps to increase the wing surface area for extra lift at take-off and landing. Concorde did not have these high-lift devices, having to rely on high angle of attack (alpha) and high landing speeds, with the delta wings providing sufficient lift (vortex lift) – but this necessary high angle of attack resulted in extra drag. Therefore, the engines had to provide a high amount of power on landing in order to maintain the landing speed (a powered landing).

**Positioned for action**
Concorde F-BVFB, mounted on the roof of the Auto und Technik Museum at Sinsheim, is posed as for take-off, with secondary nozzles in the slightly closed 'noise abatement' position.
*Photo: Valder137 / Wikimedia Commons*

All these factors combined with 6 electronic control boxes per powerplant assembly (2 intakes, 2 throttle and fuel, 1 primary nozzle, 1 reheat and reverse thrust) to give Concorde the power which made it the only commercial aircraft to be able to maintain Mach =2.0 cruise for 2–2.5 hours (with the possible exception of the Mach =3.0 SR-71 Blackbird, which had had to have refuelling during sustained supersonic trans-Atlantic crossings). So there it is – a simple(!) idea, but very complicated technically. Powerful boosters at the front, powerful engines in the middle, sophisticated exhausts at the back, all combining to allow Concorde to do what she did best.

All of this information is readily available on other sites, but my purpose was to bring it all together in an attempt to convey just what a technological triumph Concorde was in the days of her design and gestation, when ideas became reality through far-sighted and clever designers without massive computer design power. Pen and paper, drawing boards, slide rules, paper model aeroplanes, and genius thinking were the tools of choice – and the result has not been bettered. So those very familiar 'boxes' under the wings were indeed the 'beating heart' of Concorde, a totally revolutionary concept and design for a civil aircraft.

I make no excuses for eulogising about this layout – it just goes to show how Concorde was an aircraft of the future, now sadly consigned to the past. But we can still marvel at her design, visit the static exhibitions around the world, and appreciate what can be achieved by people with vision and conviction, whilst inspiring the engineers and scientists of the future.




**Stages of flight**
These diagrams show the positions of the air intake ramps and the airflow during the four main operating phases of the assemblies.
*Image: Source unidentified*

## Tech Log

**Q** *At the beginning of the take-off roll, when the power levers are set to full, the engines are working hard to provide all the air required. At what point and speed does the forward motion, i.e., oncoming air speed, overtake the 'hoovering' effect of the engines and provide the required air supply?*
*Nigel Ferris*

**A** Reply from Ian Kirby, former Senior Engineer Officer: The engines require about 275lb of air each per second on take-off, a very big suck. Even in the cruise at M=2.0 the engines still exert a slight suck on the air entering them at about M=0.5.

# Concorde watch

## Concorde G-BOAG

**British production aircraft**

**Location:** Museum of Flight, Seattle, USA
**Reporter:** Capt. Derek Woodley
**Date:** 17 March 2017

In early November last year (2016) I was fortunate enough to find myself in Seattle. Now, we all know Seattle is the home of Boeing with their two large production plants at Everett and Renton, but close to the city is also King County International, a municipal airfield that is more commonly known in the aviation world as Boeing Field.

Boeing Field is the place where many Boeing customers go to pick up their purchases and fly away their brand new airliners. However, it is also home to the Museum of Flight.

This is a fabulous aerospace museum with exhibits charting the history of aviation and space travel from earliest times up to the carbon fibre revolution and the Boeing 787. Although, as you would expect, most of the exhibits have their origins in the USA, this is also the home of Concorde G-BOAG.

### A personal tour

Having made our travel arrangements for Seattle and to see AG, my son and I checked the museum website one last time only to find, to our dismay, that the Pavilion that houses Concorde would be closed to the public at the time we had planned to visit. This was to allow the addition of more aircraft and the repositioning of others within that facility.

Yet all was not lost! We emailed the museum to make them aware of my connection with Concorde and to do a little pleading, and they very kindly offered to arrange private access to AG and even remove the Plexiglas screening that normally prevents access to the aircraft flight deck. I think they were keen to pick my brains a little, as their knowledge of Concorde and its supersonic operation was, as you might expect, rather limited.

**Flight deck view**
The immaculate flight deck, with the co-pilot's headset still hanging on the control column – as if G-BOAG were ready to take off again...
*Photo: Captain Derek Woodley*

So I am now able to report first hand on the condition of Concorde G-BOAG. She has been, and is being, very well cared for indeed. Although she had been outside in the elements until the new Pavilion was constructed last year, she has obviously been kept clean and polished and has been looked after with great pride.

The aeroplane is immaculate. The flight deck and cabin have been left just as she was on the day she completed her last landing in the autumn of 2003. The co-pilot's headset is still hanging on the control column. I really thought that she was so good, we could have started her up and flown her without any problems that very day! Wishful thinking I know, but a testament to her condition.

AG is cared for with great pride by the Museum of Flight and we were told she is one of the most popular exhibits. In the refreshment café there is a silhouette of Concorde burned into the wooden backs of many of the chairs, Concorde models of various sizes are available in the Boeing store, and one can even buy a "Concorde Sandwich" that consists of peanut butter and grape jelly on white bread (not very British, I thought!).

So we can rest assured Concorde G-BOAG has a good home. Ok, in a couple of minor places she needs the exterior paint touching up, just to make her perfect. The museum were very keen to get an exact paint match, and I know that John Dun-

levy, of Duxford G-AXDN fame, has been in touch to provide the correct paint code. Work is planned when the weather is warmer.

Considering this museum relies entirely on volunteers to maintain the aircraft and run the museum they do a wonderful job. Should you ever be fortunate enough to be visiting Seattle, do visit the Museum of Flight and see AG. You will not be disappointed – she looks fantastic.

For the latest news on G-BOAG, see the museum website: *http://www.museumofflight.org/*

**In position**
Concorde G-BOAG inside the new Pavilion. Note she has pride of place, just in front of Air Force One!
*Photo: Captain Derek Woodley*

## Concorde F-WTSA

**French pre-production aircraft**

**Location:** Musée Delta, Orly, France
**Reporter:** Laurent Dupessey

**Date:** 22 March 2017

The team working on F-WTSA have mainly focused on interior jobs. All the electrical wiring dated from 1976 and needed to be upgraded to conform with current norms. This job is now complete.

The cabins have been reconfigured. At the back of the front cabin, around 1 metre of the structure was uncovered on the right-hand side and covered with plexiglass (a bit like in G-BBDG). There is a small middle cabin (like before). The aft cabin still has the old stands with pictures and screens. In addition, the aft cabin has been fitted with normal seats from Air France (not Concorde) in the first half, where visitors can sit and enjoy movies from the central TV screen above the aisle. The second half is not for public access at the moment; it is fitted with older seats, with among them at least 4 to 5 original red Concorde Air France seats.

**Machmeter**
This exact working reproduction of the original machmeter has been fitted in the rear cabin.
*Photo: Musée Delta*


The front cabin and aft cabin now have homemade machmeters that look like the ones that were used on the development aircraft (I think G-AXDN; for sure F-WTSA and F-WTSB), and on the Air France fleet until the 80s; these were designed and made by Aerospatiale. We have reproduced a real Paris–NYC 24-minute ride to Mach 2 from take-off.

Some cabin windows have had water drained from them (there are still some to be done). The side panels have been repainted in at least half of the cabin with a more modern grey-white scheme.

The engineer's consoles in F-WTSA's front cabin were removed in 1976 by Air France before the aircraft was first put on display by ADP (Aéroports de Paris), so on the full cabin, luggage compartments and passengers' overhead lockers from a real Concorde cabin mock-up made during that time were fitted

to help adjustments. It was a way to show to visitors what they would expect from an actual aeroplane. (It was done in much the same way on G-AXDN at Duxford, where more seats were installed, but now that aircraft is being returned to the flight test installation.)

The cockpit works started at the end of 2015, when lights were restored for the first time for 40 years on instruments. More mock-ups were made and some real Concorde instruments were installed (offered or on loan). A new panel for taxi and landing lights was made to control these lights, and some of the lights can now be extended.

Some other mock-ups and a complete hydraulics panel (for the flight engineer's area) are being made so no holes will remain in SA's cockpit in 2017.

Some outside works have also been carried out. Lights have been installed in the engine exhausts. One air intake has been moved to the 'down' position (as for supersonic flight; this was done last week, and we found it was not so hard to unblock the mechanical systems). The landing and taxi lights can be extended and switched on. Tests have been carried out on the anti-collision and navigation lights, but final cabling still needs to be done.

For more detailed information on the refurbishment of F-WTSA, visit the Musée Delta website: *http://museedelta.wixsite.com/musee-delta/home*


**Evening display**
Concorde F-WTSA, with the engine exhausts illuminated, is shown to stunning effect on a summer evening, and is easily visible to aircraft landing and taking off at nearby Orly airport.
*Photo: Musée Delta*